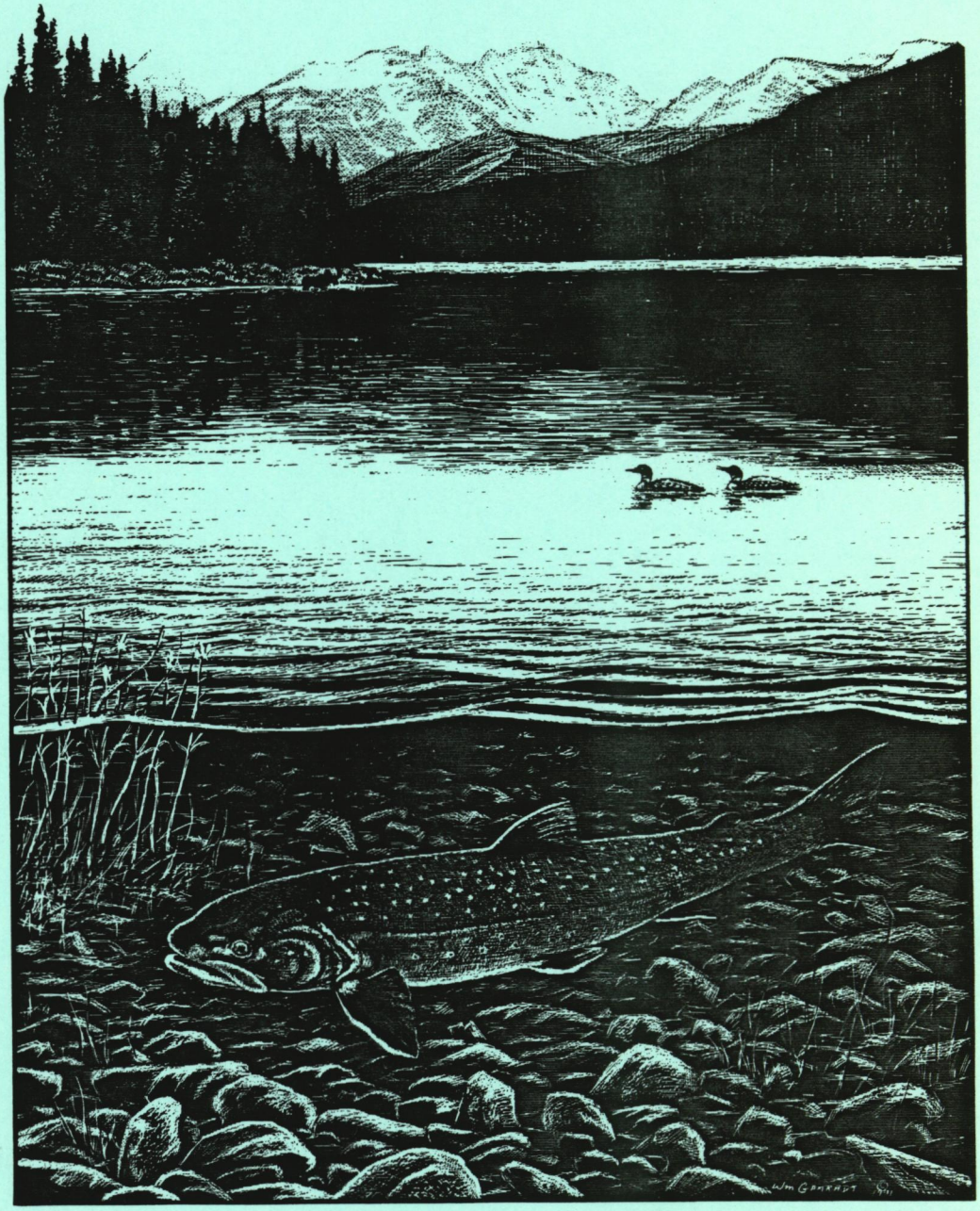
QL
638
.S2
A81
1993

United States
Department of
Agriculture

**Forest
Service**

An Assessment of the Conservation Needs for Bull Trout



LIBRARY COPY
ROCKY MTN. FOREST & RANGE
EXPERIMENT STATION

R1-96-71

An Assessment of the Conservation Needs for Bull Trout

USDA Forest Service

EXECUTIVE SUMMARY

Fishery resource managers and biologists provided information and judgements regarding the status of bull trout, a native char from the northwestern U.S. The consensus is that many bull trout populations have been lost and many others are declining primarily because their habitat is being altered by land management practices, and secondarily because of fishing and interaction with exotic fishes.

Migration, dispersal, and the connection among populations are influenced by changes in hydrologic and temperature patterns, water diversions and dams, channel conditions or barriers, and the distance among remaining populations and suitable habitats. In heavily disturbed environments populations are isolated or clustered in headwater areas increasing the probability that they will be lost.

Management actions are often spread widely throughout a basin to minimize impacts in any single stream. The use of habitat thresholds or levels of acceptable disturbance are likely to create homogeneous conditions among streams that cluster about the threshold, rather than a more natural mosaic or range of habitat and population conditions. When habitat disruption is spread among all populations it is likely that they all will decline during unfavorable periods in the regional environment (drought, for example). If conditions are severe or prolonged the potential for regional extinction is increased.

Planning and project assessments should address needs of both local and regional populations. Maintenance of strong populations of bull trout in the best possible habitats throughout the landscape and of the ecological processes characteristic of regional populations is the best hedge against extinction. Conservation goals that focus on maintenance of some spatial configuration of high quality habitats makes more sense than goals set through estimates of minimum viable population sizes, or goals that allow some disruption of all streams. Forest management and planning need to address ecological and regional population processes at the river basin or larger watershed scale, not just the small watersheds, individual streams, or stream reach scale characteristic of existing project assessments.

CONTRIBUTORS

Many individuals helped to complete this assessment. They are identified in the Acknowledgements Section. Materials concerning the status and trends of bull trout were compiled, coordinated, and written by R. Stowell, Region 1, USDA Forest Service, and P. Howell, Region 6, Umatilla National Forest, USDA Forest Service. B. Rieman and J. McIntyre, Intermountain Research Station, USDA Forest Service compiled, synthesized, and wrote the materials concerning habitat and demographic requirements of the species.

An Assessment of the Conservation
Needs for Bull Trout

USDA Forest Service

INTRODUCTION

Bull trout Salvelinus confluentus have been included as members of the "Alpinus complex" (Arctic char S. alpinus and Dolly Varden S. malma) (Phillips et al. 1992). Only in recent years have bull trout been recognized as a species separate from S. malma (Cavender 1978; Bond 1992; Haas and McPhail 1991). With that recognition has come a growing concern about the condition of many populations. Bull trout are considered a "Species of Special Concern" by the American Fisheries Society (Williams et al. 1989) and as a "Sensitive Species" by the USDA Forest Service (Forest Service).

We estimate that, depending on the state, from 50 to 80 percent of the known populations of bull trout are associated with public lands many of which are administered by the Forest Service. In June 1992 the Forest Service recognized the need to identify factors important in conserving bull trout and called for an inter-regional conservation assessment. The reason for the assessment was outlined on June 17, 1992 in a memo prepared by deputy chiefs Overbay and Sesco. They said,

> Species with wide geographic distributions present a unique and complex conservation challenge. Effective management frequently encompasses multiple ecosystems and forest types and must be coordinated among several Regions and forests. The Regional Wildlife and Fisheries (WLF) Directors and the WLF Washington Office Staff proposed development of inter-regional habitat conservation assessments for several selected species that will address the species' habitat requirements throughout their inhabited range on national forests and grasslands. The concept of inter-regional habitat assessments is consistent with the Forest Service Wildlife and Fisheries Program Action Plan prepared in response to the program recommendations of the Wildlife Management Institute (WMI) (refer to action plan, p. 4, action item no. 3, WMI recommendation no. 3).
>
> The finished products should include current information on the species' population status and trends; a synthesis of current information about habitat requirements; an assessment of limiting factors; and a discussion of management considerations that can be used to help the forests monitor and evaluate effects of their activities on species habitats, and refine management direction for either the forest plan or project decisions if found necessary.

This is that assessment including review of the current status and distribution of the species and causes for its decline. We consider the processes leading to extinction of populations, and outline a conservation approach for minimizing the risks of extinction for bull trout. The habitat and demographic needs are described in greater detail in Rieman and McIntyre (1993).

DISTRIBUTION OF BULL TROUT IN THE NORTHWESTERN U.S.

Bull trout originated in the Columbia River Basin (Cavender 1978) and dispersed through headwater exchanges and perhaps ocean migrations (Bond 1992). The known range of bull trout extended from the McCloud River in the northern California to the headwaters of the Yukon River in southern Alaska (Bond 1992) and included primarily the states of Oregon, Washington, Idaho, and Montana and the Canadian provinces of British Columbia and Alberta. Natural climatic warming and loss of cold water habitat since the Pleistocene period exacerbated by effects of human activities have reduced their distribution (Cavender 1978). Bull trout no longer exist in California, although a few fish may have survived a reintroduction using fish from Oregon. Nevada has one population in the upper Jarbidge River near the northern border. This population now represents the southernmost distribution of the species.

BIOLOGY AND LIFE HISTORY

Bull trout spawn in the fall from August through November (McPhail and Murray 1979; Armstrong and Morrow 1980; Shepard et al. 1984; Brown 1992) and embryos incubate over winter. Hatching occurs in late winter or early spring (Weaver and White 1985), but the alevins may feed and grow within the gravel for an extended period after yolk absorption (McPhail and Murray 1979). Emergence occurs from April through May (Needham and Vaughan 1952; Shepard et al. 1984; Pratt 1992; Ratliff 1992) after peak discharge (Weaver and White 1985).

Resident and migratory (fluvial, adfluvial, or anadromous) life history strategies exist throughout the range. They live together (Jakober 1992), but may be separate populations. Resident populations are often found in small, headwater streams where they spend their entire lives (Thurow 1987; Goetz 1989, Mullan et al. 1992). Migratory forms rear in tributary streams for several years (Bjornn 1957; Shepard et al. 1984) before migrating downstream into a larger river (fluvial form), lake (adfluvial or lacustrine form), or ocean (anadromous) where they rear for several years before returning to tributaries to spawn (Bjornn 1957; Shepard et al. 1984).

Most remaining bull trout populations are thought to include resident forms that remain in their natal streams. Most of the documented information on the life history of bull trout is based on migratory fish, primarily adfluvial populations. Little specific information on resident life history types is available. Anadromous populations may exist in Washington (Mongillo 1992).

The loss of fluvial and adfluvial life histories is a major concern for the viability and stability of populations (Ratliff and Howell 1992). Migratory fish are larger than resident fish, have greater reproductive potential, and may be less likely to hybridize with brook trout Salvelinus fontinalis because of the large size difference.

Resident adults range from 150 to 300 mm in length (Goetz 1989; Mullan et al. 1992) while migratory fish commonly exceed 600 mm (Shepard et al. 1984, Pratt 1985; Goetz 1989). Growth differs little between forms during stream residence but diverges as migratory fish move into larger and more productive waters. Large differences in growth and other life-history characteristics among populations are likely to lead to large differences in the resistance and resilience of populations to disturbance.

First maturity in migratory forms occurs between 5 and 7 years (McPhail and Murray 1979; Fraley and Shepard 1989). Both annual and alternate year spawning may occur (Block 1955; Pratt 1985; Fraley and Shepard 1989; Ratliff 1992). Emigrants from Flathead River tributaries include age 1, 2, and 3 fish (Shepard et al. 1984). Four or more year classes could compose any spawning population, each with up to three outmigration strategies (four if resident fish spawn with migratory fish). Although one

or two year classes may dominate the outmigration and spawning escapement (Shepard et al. 1984), as many as 12 to 16 combinations could occur in any spawning year.

The multiple life-history strategies found in bull trout, and the distribution of populations among river basins, watersheds, and streams represents spatial and genetic diversity. Genetic structuring (Leary et al. 1991) results when migratory fish home to natal streams or through other mechanisms that tend to isolate reproductive groups (Reisenbichler et al. 1992). Because habitats and environments tend to be heterogeneous, a logical consequence of this behavior is that natural selection results in adaptation to local environments, and structuring within the larger population. Under normal environmental variation such behavior will also result in collections of individuals or subpopulations that do not respond to environmental change in synchrony. Maintenance of the inherent diversity among populations will be important to long-term persistence in a variable and changing environment.

INTERACTION WITH OTHER SPECIES

Bull trout eat terrestrial and aquatic insects, macro-zooplankton, mysids and fish (Shepard et al. 1984). Fish are common in the diet of bull trout as small as 110 mm long, and larger individuals may feed almost exclusively on fish (Shepard et al. 1984). Bull trout in several river basins evolved with large populations of juvenile salmon and their abundance declined with the decline of the salmon (Ratliff and Howell 1992).

Interactions between bull trout and native species have not been widely studied. Available research indicates that selective segregation in resource-use reduces direct competition (McPhail and Murray 1979). Interactions with introduced non-native fishes, however, may have important influence on the persistence of many bull trout populations. Introduced brown trout Salmo trutta and rainbow trout have been associated with the decline of bull trout populations (Bond 1992; Mullan et al. 1992). The expansion of exotic lake trout S. namaycush may have depressed migratory bull trout in Flathead Lake, Montana (Weaver 1992), and in other systems (Donald and Alger 1992).

Hybridization appears to be a common problem where isolated or remnant bull trout overlap with congeneric brook trout (Cavender 1978; Leary et al. 1991; Markle 1992). Hybrids are likely to be sterile and exhibit high developmental instability (Leary et al. 1991). A progressive shift from bull trout to brook trout dominance occurred after the appearance of brook trout in Lolo Creek, Montana (Leary et al. 1991). Reaches of the south and middle forks of the Salmon River, Idaho that supported large numbers of brook trout contained few, if any, bull trout (Thurow 1987). Similar results have been observed in the Pend Oreille (Pratt 1985), Bitterroot (Clancy 1993), and Swan (Leathe and Enk 1985) rivers.

HABITAT REQUIREMENTS AND DISRUPTION

The patchy distribution of bull trout in relation to other species suggests relatively specific habitat requirements and populations that may be prone to habitat disruption and fragmentation (Fraley and Shepard 1989). Five habitat characteristics (stream channel stability, habitat complexity, substrate composition, temperature, and migratory corridors) appear to be particularly important for bull trout (Rieman and McIntyre 1993). Other factors may limit or influence populations, but these five appear most prominently in the available information, and are likely important elements for maintenance of a healthy population of bull trout.

We could not find clear limits or thresholds in habitat condition that directly control the distribution and abundance of the species. New work that defines both the spatial and temporal variation in habitat characteristics of bull trout will help identify such habitat requirements. More rigorous attempts are needed to describe the range of variability in available habitat conditions and complexes

tolerated by populations. In the absence of new information, managers must consider changes in habitat characteristics a threat to the persistence of bull trout.

Human activities can strongly influence habitats for bull trout. Timber harvest, livestock grazing, mining, water diversion, and associated activities affect the amount, form, and function of woody debris, the composition of substrate, and the stability and form of channels (Bisson et al. 1987; Sullivan et al. 1987; Hicks et al. 1991). Clearcutting and watershed disturbance are linked to increased water yields, bedload movement, or more frequent flooding (Sullivan et al. 1987; King 1989; Chamberlain et al. 1991), and to channel instability (G. Kappesser, Panhandle Forests, Idaho, personal communication of unpublished data). The distribution and abundance of bull trout has been associated with patterns of habitat condition that suggest habitat disruption has directly influenced many populations. Clancy (1993) summarized the presence of bull trout populations in the Bitterroot River basin and found that most remaining populations were in the least disrupted watersheds. Bankfull flows commonly transport 80 to 100 percent of the bed materials in heavily harvested watersheds on the Idaho Panhandle Forests. The instability of these channels may explain the disappearance of bull trout in the Coeur d'Alene drainage (D. Cross, Panhandle National Forest, personal communication), since eggs deposited in the fall may not survive winter events. Edwards and Burns (1986) linked levels of fine sediments in streams to road densities. Weaver and Fraley (1991) and Shepard et al. (1984) linked levels of fine sediment to other activities disrupting watersheds. Substrate composition has been correlated with bull trout distribution and abundance (Leathe and Enk 1985; Thurow 1987; Weaver and Fraley 1991).

Stream temperatures have been altered by changes in the forest canopy and riparian shading, in water yield, and in hydrologic patterns (Anderson 1973; Rishel et al. 1982; Barton et al. 1985; Beschta et al. 1987; McGurk 1989). Although there is no direct evidence that alteration of temperature patterns has influenced the persistence or distribution of bull trout, a strong association of temperature with distribution makes such responses likely (Rieman and McIntyre 1993).

Dams and irrigation diversions that dewater or block streams are common in many interior basins. Channel aggradation and high bedload movement cause subsurface flow in many streams in northern Idaho. In some streams in the Flathead River basin, dry channels blocked spawning bull trout leading to a year-class failure (Weaver 1991).

Links between land management and stream channel disruption are well defined. Such changes have and will degrade bull trout habitats, but we cannot accurately predict how a specific activity, or the accumulation of activities, will influence the abundance, resilience, or long-term persistence of a population. Managers have used thresholds of acceptable change for specific channel or watershed characteristics (such as percent fine sediment, or water yield) to minimize the risk to individual populations. Such thresholds must be used cautiously because some watersheds and populations may be far more sensitive to disruption than others (Hicks et al. 1991).

STATUS OF BULL TROUT

Information concerning the status of bull trout was obtained through a survey of biologists from state and federal agencies, tribal governments, and private industry in California, Oregon, Washington, Idaho, Montana, and Nevada (Table 1). Some habitat and population data are available for about half of the populations (Table 2). The data are not the result of a systematic survey of all available data and the quality was not always consistent across sources. The data were taken from the survey forms (appendices A and B) as provided. The data sheets are on file in Region 1, USDA Forest Service, Missoula, Montana. In most cases the data represent the best professional judgment of the biologists based on specific experiences with individual streams and populations. Information indicating that bull trout no longer exist in some areas is likely to be more reliable as a basis for decision making

than are trends for specific populations. Present and planned surveys by many agencies should help to overcome some of these deficiencies in the near future.

For purposes of this survey, bull trout populations were defined, by the biologist contributing the data, on the basis of "suspected" reproductive isolation. Genetic data for differentiation are available for a few populations (Leary et al. 1991) and indicate reproductive isolation among populations is common. Even in the absence of genetic information, populations may reasonably be delineated in areas where they have become isolated and fragmented or separated by migration barriers.

In Oregon (Table 3) bull trout occur primarily in the upper portions of tributaries of the Columbia and Klamath rivers. The Klamath River was formerly connected to the Columbia Basin via the Snake River (Hocutt et al. 1986). Eighteen percent of the populations identified by Ratliff and Howell (1992) were classified as "probably extinct." The greatest losses of distribution have occurred in the mainstem reaches of most rivers and in Oregon's Willamette Basin. The only populations of note remaining in the west side of the Cascade Mountains are currently found in the McKenzie River. Many populations have become fragmented and isolated in the upper reaches of the drainages (Ratliff and Howell 1992).

In Idaho, bull trout no longer occur in many areas within their historic range. Of the populations with sufficient information to judge status, 72 percent are declining (Table 1).

The largest number of populations in Washington (Table 4) are on the Olympic Peninsula and in river systems draining into the northern portion of The Puget Sound (Mongillo 1992). Most losses in distribution have been east of the Cascade Range. Three populations are extinct (Okanogan, Lake Chelan, and lower Yakima River). Populations in the Blue Mountains, upper Yakima River, and the Lewis and Cedar rivers in western Washington have become fragmented. In the mainstem Columbia River, bull trout tend to be found only in locations near tributaries that contain bull trout.

Although the data are presently under review (M. Enk, Flathead National Forest, personal communication), it is likely that bull trout once were more widely distributed in western Montana than at present (Table 5) (Thomas 1992). East of the Continental Divide, bull trout are native to the St. Mary's River. They were estimated to occur in 42 percent of their potential historic range (Thomas 1992). Except for the Flathead, Swan, and Rock Creek drainages, bull trout in Montana now exist mostly as resident populations.

Of the 438 populations identified only 5 percent are classified as secure or increasing and 16 percent are thought to be stable (Table 1). Stable indicates the populations are not increasing or decreasing. Sixty percent of the populations with sufficient information on trends in population size are thought to be declining. Fifty-eight percent of the populations that could be classified were considered remnants. The status of half of the populations is unknown.

The biologists were asked to assess what they believed to be the causes for either presumed declining or loss of populations. They believe that forest management activities are the primary factor affecting bull trout habitat (Table 6). Grazing, other agricultural practices, dams and hydropower projects, and other factors are believed to each affect between 21 and 27 percent of populations. Alteration of physical habitat (woody debris, pools, substrate) was identified as the major impact on habitat quality affecting 49 percent of the populations. About 18 percent of the populations had favorable physical habitat, flow, or water quality.

Other than physical habitat, the principal threat to bull trout populations is believed to be interaction with non-native species, primarily brook trout (Table 7). Hybridization and competition between brook trout and bull trout can lead to the eventual displacement of bull trout (Leary et al. 1991). Habitat disruption may also favor introduced species (Hobbs and Huennke 1992).

Bull trout can be overharvested, so harvest regulations in Oregon, Idaho, Washington, and Montana have become more restrictive. Taking of fish by anglers and poachers are still considered a problem for 19 percent of the populations (Table 7). Forty-two percent of the populations were considered vulnerable to harvest. Because migratory bull trout are large and spawn in small tributaries at low flows in the fall, poaching is a concern where spawning areas are easily accessible.

EXTINCTION

Fragmentation and disruption of habitats for bull trout isolate populations, and isolate or eliminate life history forms. Those effects probably have influenced both local and regional extinction. The processes of extinction are thought to be linked to resilience of local populations as well as the condition, structure, and interaction of populations and habitats at larger scales (Rieman and McIntyre 1993).

Deterministic extinctions may occur with the cumulative loss or otherwise persistent change of a critical component in the species' environment (Gilpin and Soulé 1986). If the environment changes in such a way that it is no longer suitable for a population, recruitment or survival rates decline to the point that compensation in one cannot mitigate the other. When population growth is negative, the population declines to extinction unless conditions change. Bull trout populations might decline, for example, with elimination of pools or woody debris that are necessary as overwinter habitat; or with an increase in fine sediments that degrade spawning habitats and lead to increased mortality of incubating embryos. Competition, or predation, might increase with the introduction of exotics. Changes that individually might be tolerated may cumulatively result in extinction. Displacement of bull trout by brook trout, for example, may occur more commonly in degraded habitat. Mortality from some causes may increase as populations become smaller, even with no further change in the environment. Such depensatory effects may be particularly relevant for salmonids (Peterman and Gatto 1978; Peterman 1977; Rieman and Apperson 1989; Rieman and Myers 1991, McIntyre et al. 1988). Any habitat change that results in a reduction in survival or growth at any life stage for more than a single generation represents an increase in the risk of a deterministic extinction.

Stochastic extinctions result from demographic or environmental factors (Leigh 1981; Shaffer 1987, 1991; Ginzburg et al. 1990). Demographic stochasticity is thought to be unimportant for most species unless population sizes are small (20 adults) (Leigh 1981; Shaffer and Samson 1985; Quinn and Hastings 1987; Shaffer 1987) and important to persistence of bull trout only when populations have been severely restricted through other causes.

Environmental stochasticity includes chronic and catastrophic effects (Shaffer 1987, 1991). These represent the variation in survival and birth rates, that can be attributed to environmental variability (temperature and stream flow, for example) and to the frequency of extreme events such as flood, drought, fire storms, and debris torrents. Theoretically, population size and the magnitude of temporal variation will determine the probability of extinction for a population in some given period of time (Leigh 1981; Dennis et al. 1991; Boyce 1992). As a population is restricted in size, or as the variation in number increases the predicted mean time to extinction will decrease. Habitat change may influence the amount of environmental variation and the sensitivity of a population to that variation. Small populations are expected to vary more than large populations (Gilpin and Soulé 1986). They are likely to experience high temporal variation, and lower genetic and phenotypic diversity (Gilpin and Soulé 1986; Shaffer 1987; Saunders et al. 1990). Populations in complex habitats are expected to be more stable than populations in simple or restricted habitats because they have more refuges from extreme events and greater capacity to buffer the effects of environmental change (Schlosser 1982, 1991; Saunders et al. 1990; Sedell et al. 1990).

Historically, extinction through stochastic processes may have been unimportant for most local and regional bull trout populations. However, with the loss of habitat many populations have declined in size and distribution relative to historic conditions and have been restricted to marginal or highly

variable habitats in headwater areas (Mullan et al. 1992). Even if these habitats are pristine, stochastic effects represent a risk. Without any further habitat loss, further loss of already restricted bull trout populations can be anticipated (Rieman and McIntyre 1993).

Conservation of a species depends on protection of its genetic diversity because of unpredictable conditions in nature. The consequence of losing diversity may be loss of genetic combinations that permit survival in highly variable environments. Although adaptations to local conditions are difficult to identify, hypotheses concerning their presence generally are supported as data become available (Hynes et al. 1981; MacLean and Evans 1981). At present, available data do not provide a basis for specifying the minimum amount of genetic diversity that must be maintained in any bull trout population to ensure its persistence.

Thinking in species conservation has focused on genetic issues associated with small population size and isolation (Franklin 1980; Shaffer 1991). More recent work suggests that most populations are at higher risks of extinction through environmental stochasticity than through inbreeding or the loss of genetic variation (Shaffer 1987; Lande 1988; Stacey and Taper 1992). It is likely that managing to minimize risk associated with stochastic and deterministic effects will also minimize genetic risks.

Local extinctions are thought to be a common part of the regional population dynamics for many species (Hanski and Gilpin 1991). Regional persistence likely depends on multiple local populations in complex habitats to spread the risk of synchronous extinctions (Morrison and Barbosa 1987; Quinn and Hastings 1987). Strong populations can provide sources for recolonization (Sjogren 1991; Brown and Kodric-Brown 1977) or support of weak populations through dispersal of surplus animals (Hanski 1985; Pulliam 1988). Metapopulation (regional population) dynamics may be particularly important to the persistence and recovery of populations following catastrophic events (Yount and Niemi 1990) but probably play a role in normally variable environments as well. An increasing number of analyses from a variety of species suggest few local populations are likely to persist in isolation from other populations (Shaffer 1987; Hanski 1991: Sjogren 1991; Stacey and Taper 1992). Similarly, isolated bull trout populations appear to face relatively high probability of extinction (Rieman and McIntyre 1993). Current theory suggests the probabilities of persistence and relative stability of a regional populations of any species are strongly influenced by the sizes, spatial distribution, temporal variation and synchrony, and dispersal among the local populations (Hanski 1991; Sjogren 1991; Fahrig 1992).

MANAGEMENT CONSIDERATIONS

Conservation of bull trout cannot proceed in isolation from other conservation efforts. Management that attempts to maintain a target species rather than the integrity and function of ecosystems is piecemeal and destined to omit important components and processes that we have yet to understand (Hunter 1991). Environmental requirements for other sensitive fish, amphibians, birds, and mammals probably have many common elements. The distribution of conservation areas will overlap, and the general need for ensuring natural diversity, a more natural disturbance regime, and connectedness among important habitats will be central to most efforts. Design of a comprehensive management system that satisfies the critical needs for all components may be extremely complex and difficult but the possibilities have been recently outlined (Johnson et al. 1991; USDA 1993). Murphy and Noon (1992) developed an iterative approach to optimize the selection of conservation reserves for spotted owls that was based on the critical needs of the animal and the availability of suitable and manageable (ownership issues) habitats. A similar approach is needed for bull trout and the associated species.

Under existing management, diversity can be maintained in the immediate future by identifying and protecting core areas from throughout the range of the species. A core area is a system of watersheds within a larger basin. Each watershed is the habitat for a local population that interacts with other local

populations throughout the larger basin. For the long-term, a system of core areas with potential for long-term persistence and the restoration and maintenance of ecological and metapopulation processes are necessary. Biological, physical, and social considerations will constrain the number and distribution of core areas that can be established for conservation of bull trout. The biological and physical constraints for such a system can be identified from Rieman and McIntyre (1993) and the review and efforts of others to develop conservation strategies and the emerging principles of aquatic reserve design and ecosystem management (Saunders et al. 1990; Moyle and Sato 1991; Reeves and Sedell 1992; Murphy and Noon 1992; Frissell 1993). From these we have identified five criteria that should guide the selection and development of core areas suitable for bull trout conservation:

1. Core areas for bull trout should contain a collection of key watersheds that support high channel and substrate complexity and stability, low levels of fine sediments, temperature and hydraulic regimes that are consistent with unaltered basins, and intact and open migratory corridors. Because thresholds in habitat condition cannot address the needs of all life-history forms, or all possible habitat-population relations, key watersheds within the core area should be managed for essentially no disruption or alteration of natural processes.

Areas outside key watersheds might be managed under less restrictive standards and guidelines, but it is critical that ecologic, and hydrologic processes throughout the entire core area are maintained or restored (USDA 1993; Frissell 1993). Disturbance in non-key watersheds for example cannot compromise migratory corridors, riparian shade, or adult wintering areas that often will fall outside the key watersheds (see Frissell 1993 for a discussion of the restoration and maintenance of "nodal" habitats).

2. Core areas should be selected from the best remaining habitats or systems that present the best or most realistic opportunities for restoration. Systems with the greatest remaining spatial and life-history diversity offer the best opportunity for long-term persistence.

3. The core areas should provide for a widely distributed collection of local populations within the identified key watersheds or streams including resident and migratory life history forms. Local populations of migratory bull trout will be associated with watersheds ranging from 25 to 100 sq km. Resident populations will be associated with individual streams or watersheds of 5 to 25 sq km. Ideally there should be more than 5 local populations that support moderate to large populations (see Rieman and McIntyre 1993).

4. The core area should be large enough to incorporate, as much as possible, the genetic and phenotypic diversity inherent within any historic regional population, but small enough to ensure that the local populations effectively connect. The intent should be to make core areas large enough to incorporate the full function of the relevant metapopulation. For most regional populations (metapopulations) of bull trout, core areas will be represented by basins between 250 and 2500 sq km.

5. Core areas should be replicated throughout the historic range of the species. Any serious conservation effort must move toward restoring and maintaining populations throughout the range not just maintaining the existing strong populations. It is impossible to identify conservation areas that meet all of the preceding criteria throughout the historic range. That should not imply that conservation attempts should be abandoned in the less than perfect sites. It simply means a more difficult job of ensuring persistence. Actions that prevent or slow recovery of remaining populations, or movement of a system toward the ideal characteristics of a conservation area, increase the risk of extinction.

IMPLEMENTATION

A plan for conserving bull trout should 1.) identify core areas, and 2.) provide management guidelines to protect and restore those systems. To follow the earlier outline, for example, the first part of the

plan would include the results of intensive study of topographic maps, available population distributions and habitat information, and input from biologists familiar with bull trout life histories and likely metapopulation structure. The plan would include standardized concepts and methods for core area delineation to be applied consistently across the entire range. A team, including biologists knowledgeable about contemporary concepts and methods in conservation biology, could be assigned the task of plan development. They would be expected to complete the mapping to specify what is to be protected.

Once the core areas have been identified, how they will be managed would be described. Distributions of populations will no doubt cross administrative boundaries necessitating collaborative planning efforts between states, tribes, and federal agencies. Every effort should be made to tie recovery strategies to the needs of other species and riparian community protection (for an example, see Appendix 5-K in USDA 1992).

It is critical to establish management standards and guidelines for habitat restoration and protection. These standards and guides would center around maintaining or restoring healthy watersheds and ecological processes, channel and hydraulic stability and complexity, low sediment levels, migration passage, water quality and quantity, and appropriate thermal regimes. Some general approaches to habitat management (Moyle and Sato 1991; Frissell 1993; Appendix 5-K in USDA 1992) may be appropriate, however, management standards and guidelines will need to be specific to a metapopulation and its supporting ecosystem.

The role of the land managers in partnerships with states and tribes is crucial to the success of this plan. Species management will be necessary to protect the populations while habitats are being protected and restored. Regulation of harvest, increased enforcement, increased public education, and reduced competition from exotic fish species will be necessary for the recovery of the species throughout its range. Species management plans developed by each state need to be considered during development of habitat conservation strategies.

MONITORING

Populations - Once a program is in place, monitoring is necessary to demonstrate its success. At a minimum, inventory programs should provide sufficient data to demonstrate that bull trout persist throughout the management area. More intensive monitoring is needed to identify and assess trends in abundance.

We suggest a hierarchical approach to inventory and monitoring based on the utility, urgency, and cost of information.

1) The first need is to know the existing distribution of bull trout. At present, we lack even basic inventory (presence/absence) throughout much of the species' range. Without inventory, even designation of appropriate conservation areas becomes a difficult if not impossible task. If the complete distribution is unknown, sites near the periphery of the unit are most likely to be in question, so sampling should be directed to these locations. Once the boundaries of the distribution are known, watersheds in questionable condition altered either by natural or human-caused disturbances are likely candidates.

Generally, the historic distribution and the frequency with which population segments are lost naturally are unknown. Therefore, streams where bull trout have not been found, but reasonably might be expected to occur, should also be included in the initial inventory to enable detection of bull trout dispersal and re-colonization through future monitoring.

2) The next logical focus for additional monitoring resources is to provide estimates of relative abundance rather than just presence/absence information. Basin wide inventories of spawning escapement such as those conducted periodically in the Flathead (Weaver 1992) and Pend Oreille (Pratt 1985) river systems are excellent examples that show the relative importance of local populations.

3) True monitoring implies temporal replication. Once the general distribution and spatial diversity are understood, repeating all or some portion of the sampling through time can define the trends necessary to evaluate success of management.

Limited monitoring resources should be focused in areas that represent the greatest jeopardy to bull trout. The lowest level may be to monitor bull trout in areas most intensively managed or otherwise considered to be at the highest risk. Progressively higher levels include monitoring a sample of the available streams in both impacted and unimpacted areas where there are no previous records. A selection of representative streams maintained through time could be used as an index of spatial diversity (see Rieman and McIntyre 1993). At still higher levels, monitoring could include all areas in a basin to detect changes both in abundance and true spatial diversity.

Regardless of the type or intensity of monitoring possible, care is needed in program design. Monitoring or inventory variables need to be consistent with the goals of the conservation plan. Existing data can be used wherever possible to consider sampling design, statistical power, and the criteria for decisions.

Habitat - A typical approach in attempts to develop fish habitat relations has been to associate densities of fish with channel characteristics at reach and habitat unit scales. This model assumes that "critical" habitats are those preferred or heavily used and that changes in the quality or abundance of such habitats will ultimately lead to a decline in a population. Although such models are often useful for describing fish distribution within a basin, they typically lack the generality to be useful outside of the area for which they were developed. Such generality is critical for more quantitative risk assessment.

The important characteristics of a fish population do not result simply from the summation of number and quality of local habitat units inhabited by individuals but also through larger scale processes consistent with range of the population or metapopulation. Different variables are important in explaining the distribution and abundance of animals at different scales. Metapopulation theory suggests that processes that influence the relative size and temporal variation in a population and the condition of and proximity to other populations will be critical to the persistence of both local and regional populations.

Work to define fish habitat relations needs to be focused at higher scales. Linking fish management to ecosystem management will depend on that perspective. The generality in models necessary for prediction and risk assessment across watersheds and basins will likely come from models developed at that scale. Recognition of large scale processes or regions will also allow for more efficient sampling and continuing research relevant to smaller scale processes or relationships. For example, if we recognize that the geographic distribution of bull trout is limited by temperature or watershed size, research intent on understanding the local influence of habitat condition can be focused far more efficiently in areas that are clearly suitable on the larger scale than attempting to sample everything.

Established habitat sampling protocols are intensive and expensive requiring sampling throughout a substantial portion of a watershed. We cannot maintain that intensity of sampling and gain much if any information at the larger scales. Use of presence/absence data (Buckland and Elston 1993; Taylor 1991) offer promise for large scale inference of habitat suitability, and spatial processes and

dynamics relevant to persistence. Coarse scale habitat characteristics discernable from land types, geomorphic or physiographic associations and the relative magnitude and type of disturbance might be readily incorporated. Sampling for such approaches will be necessary in any case just to define the range and distribution of species necessary for future management assessments.

PRIORITIES FOR RESEARCH

Habitat requirements - Bull trout are associated with specific habitat types but the range of conditions tolerated by stable populations is unknown. Temperature is likely an important and inflexible habitat requirement but its influence has not been totally defined. Definition of sutiable habitat on a coarse scale (physiographic, geomorphic) could be an important contribution.

Bull trout/other species interaction - Brook and lake trout appear to be an important threat to the persistence of many bull trout populations. Hybridization has been identified as a mechanism of displacement by brook trout but, factors that may influence the interaction are unknown. It is not clear whether displacement is inevitable in many habitats or whether habitat disruption hastens the process. The relative risks of isolation and invasion are unknown.

Metapopulation structure and dispersal - Dispersal and interaction of local populations may strongly influence the dynamics and persistence of regional populations (metapopulations) of bull trout. Dispersal mechanisms and rates are unknown, making it difficult to establish a proper scale for conservation areas. New work on fine scale genetic structuring, existing spatial distribution and correlation among populations, and simulation of regional dynamics is important.

Temporal and spatial scale of disturbance - Temporal variation in populations influence the risk of extinction through stochastic processes. Effects of flood and low flow events during migration, spawning and incubation, rearing, and overwinter have not been described. Identification of the driving factors and of the frequency, magnitude, and spatial scale of important disturbance in different geologic and climatic regions is needed.

The role of life-history forms - The interaction between resident and migratory forms is unknown in bull trout. Differences in their habitat use and requirements, or their distribution are unknown. Variation in temperature requirements throughout the range is unknown. Although it has not been demonstrated, we speculate that life-history diversity is key to persistence of bull trout.

Extinction Risks - Rieman and McIntyre (1993) made first approximations of extinction risk for some populations of bull trout. The approach did not account for complexity in life-history or the interaction among populations. New work should explore alternative simulation methods for estimating risks.

Research is currently underway to describe habitat use by bull trout and provide a basis for stronger inferences about habitat requirements. Work at INT is directed at defining the limits of distribution in relation to temperature. Other work is focusing on the risks of local extinction and important characteristics of regional populations. Inventory of bull trout has increased dramatically on forest, private, and state lands in the last year. Availability of information on both the status and distribution of bull trout should increase substantially in the next few years. Much of our understanding of the spatial processes important to regional or meta populations will come from that large scale survey and monitoring work. Such information is crucial for conservation but will also guide the development of ecosystem management.

AGREEMENTS AND PLANS

All six states where bull trout are found have completed species management plans. Goals for the recovery of the species will be achieved through conservation agreements/strategies now being developed by each state.

The Governor of Montana recently convened a roundtable of agencies, industry and environmental groups to discuss bull trout population status, habitat needs, and possible recovery strategies in Montana. The participants agreed that plans for recovery of bull trout must include representatives from many agencies, input from managers and experts, and the public. The roundtable adjourned after agreeing to work cooperatively to produce a bull trout recovery plan by January 1995.

A general agreement has been reached in Oregon to coordinate bull trout work among the agencies, tribes, and utilities. Discussions are proceeding on approaches and strategies for recovery.

Idaho was a participant on Montana's Roundtable and agreed to collaborate on any recovery plan where state jurisdictions overlap. They also intend to initiate a bull trout agreement similar to Montana's. They have signed a Memorandum of Understanding with the Boise National Forest and USDI Fish and Wildlife Service to implement a Conservation Strategy to protect and enhance bull trout in the Gold Fork River of Idaho.

There are two forests with conservation plans approved by Forest Supervisors. The Wenatchee National Forest has produced a Management Guide in cooperation with the Washington Department of Wildlife. The Idaho Panhandle National Forest recently approved implementation of bull trout habitat conservation plans for the three aquatic ecosystems on the Forest.
More forest-level plans are expected in the near future.

ACKNOWLEDGMENTS

The authors would like to thank the many people that assisted in the completion of this project. Special thanks to the state biologists who devoted many hours attending all the meetings, coordinating the data collection, and producing the maps. These people are: Tom Weaver, Montana Fish Wildlife and Parks, Paul Mongillo, Washington Department of Wildlife, Bill Horton, Idaho Department of Fish and Game, and Bob Hooton, Oregon Department of Fish and Wildlife. This project required many coordination meetings where information and ideas were exchanged. The following people were of enormous help and provided input for the report: Dave Cross, Lori Nordstrom, Rich Torquemada, Russ Thurow, Debby Myers, Chris Hunter, Don Ratliff, Seona Brown, Ginger Thomas, Bill Ruediger, Dave Heller, Doug Perkinson, Ken MacDonald, Larry Brown, Gordon Reeves, Robb Leary, Wade Fredenberg, Dave Buchanan, Rick Swanson, Pat VanEimeren, Len Walch, Lynn Decker, Chris Clancy, Michael Enk, Kent Nelson, and Don Virgovic. A special thanks also to the many field biologists with the states, Forest Service and Bureau of Land Management who filled out the questionnaires. Shari Whitwell and Leslie Parrott were patient and helpful throughout.

LITERATURE CITED

Anderson, H. W. 1973. The effects of clearcutting on stream temperature, a literature review. Rep. No. 29. Olympia, WA: Washington Department of Natural Resources.

Armstrong, R. H.; Morrow, J. E. 1980. The Dolly Varden charr (Salvelinus malma). In: Balon, E. K. ed. Charrs, salmonid fishes of the genus Salvelinus. Dr. W. Junk Publishers: 99-140.

Barton, D. R.; Taylor, W. D.; Biette, R. M. 1985. Dimensions of riparian buffer strips required to maintain trout habitat in southern Ontario streams. North American Journal of Fisheries Management. 5: 364-378.

Beschta, R. L.; Bilby, R. E.; Brown, G. W.; Holtby, L. Blair; Hofstra, T. D. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo, E.O.; Cundy, T.W. eds. Streamside management: forestry and fishery interactions. Seattle, WA: University of Washington: 191-232.

Bisson, P. A.; Bilby, R. E.; Bryant, M. D.; Dolloff, C. A.; Grette, G. B.; House, R. A.; Murphy, M. L.; Koski, K. V.; Sedell, J. R. 1987. Large woody debris in forested streams in the Pacific Northwest: past, present, and future. In: Salo, E.; Cundy, T. W. eds. Streamside management: forestry and fishery interactions. Contribution No. 57. Seattle, WA: University of Washington, Institute of Forest Resources: 143-190.

Bjornn, T. C. 1957. A survey of the fishery resources of Priest and Upper Priest Lakes and their tributaries. Masters Thesis. Moscow, ID: University of Idaho.

Boyce, M. S. 1992. Population Viability Analysis. Annu. Rev. Ecol. Syst. 23: 481-506.

Block, D. G. 1955. Trout migration and spawning studies on the North Fork Drainage of the Flathead River. Bozeman, MT: Montana State University. Thesis. 68 p.

Bond, C. E. 1992. Notes on the nomenclature and distribution of the bull trout and effects of human activity on the species. In: Howell, P. J.; Buchanan, D. V. eds. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society: 1-4.

Brown, L. G. 1992. Draft Management Guide for the bull trout Salvelinus confluentus (Suckley) on the Wenatchee National Forest. Washington Department of Wildlife, Wenatchee.

Brown, J. H.; Kodric-Brown, A. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. Ecology. 58: 445-449.

Buckland, S.T.; D.A. Elson. 1993. Empirical models for the spatial distribution of wildlife. Journal of Applied Ecology 30:478-495.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout (Salvelinus confluentus) from the American northwest. California Fish and Game. 64(3): 139-174.

Chamberlain, T. W.; Harr, R. D.; Everest, F. H. 1991. Timber harvest, silviculture and watershed process. In: Meehan, W. R. ed. Influences of forest and rangeland management on salmonid fishes and their habitat. American Fisheries Society Spec. Publ. 19. Bethesda: 181-206.

Clancy, C. 1993. Bitterroot Forest Inventory. Helena, MT: Montana Department of Fish Wildlife and Parks. Job Completion Report F-46-R-4, Job IJ. 76 p.

Donald, D.B.; Alger, D.J. 1992. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Can. J. Zool. 71:238-247.

Dennis, B.; Munholland, P. L.; Scott, J. M. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs. 6: 115-143.

Edwards, R.; Burns, D. 1986. Relationships among fish habitat embeddedness, geomorphology, land disturbing activities, and the Payette National Forest sediment model. McCall, ID: U.S. Department of Agriculture, Forest Service, Payette National Forest.

Fahrig, L. 1990. Simulation methods for developing general landscape-level hypotheses of single-species dynamics. In: Turner, M. G.; Gardner, R. H. eds. Quantitative Methods in Landscape Ecology, the analysis and interpretation of landscape heterogeneity. Ecological Studies. 82 vol. Springer-Verlag: 438-442.

Fraley, J. J.; Shepard, B. B. 1989. Life history, ecology and population status of migratory bull trout (Salvelinus confluentus) in the Flathead Lake River System, Montana. Northwest Science. 63(4): 133-143.

Franklin, I. E. 1980. Evolutionary change in small populations. In: Soulé, M. E.; Wilcox, B. A. eds. Conservation Biology: an evolutionary-ecological perspective. Sunderland, MA: Sinauer Associates: 135-150.

Frissell, C.A. 1993. New strategies for watershed restoration and recovery of salmon in the Pacific Northwest. Pacific Rivers Council, Eugene Oregon, DRAFT March 1993

Gilpin, M. E.; Soulé, M. E. 1986. Minimum viable populations: processes of species extinction: 13-34. In: Soulé, M. E. ed. Conservation biology: the science of scarcity and diversity. Sunderland MA: Sinauer Associates. 584 p.

Ginzburg, L. R.; Ferson, S.; Akcakaya, H. R. 1990. Reconstructibility of density dependence and the conservative assessment of extinction risks. Conservation Biology 4(1): 63-70.

Goetz, F. 1989. Biology of the bull trout, Salvelinus confluentus, a literature review. Eugene, OR: U.S. Department of Agriculture, Willamette National Forest.

Haas, G. R.; McPhail, J. D. 1991. Systematics and distribution of Dolly Varden (Salvelinus malma) and bull trout (Salvelinus confluentus) in North America. Canadian Journal of Fisheries and Aquatic Sciences. 48: 2191-2211.

Hanski, I. 1985. Single-species spatial dynamics may contribute to long-term rarity and commonness. Ecology. 66(2): 335-343.

Hanski, I. 1991. Single species metapopulation dynamics; concepts, models, and observations. Biological Journal of the Linnean Society. 42: 17-38.

Hanski, I.; Gilpin, M. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society. 42: 3-16.

Hicks, B. J.; Hall, J. D.; Bisson, P. A.; Sedell, J. R. 1991. Responses of salmonids to habitat changes. In: Meehan, W. R. ed. American Fisheries Society. Spec. Pub. No. 19: 483-518.

Hobbs, R. J.; Huenneke, L. F. 1992. Disturbance, diversity and invasion: implications for conservation. Conservation Biology. 6(3): 324-337.

Hocutt, C. H.; E. O. Wilson; E. O. Wiley. 1986. Zoogeography of North American Freshwater Fishes. John Wiley and Sons.

Hunter, M. L., Jr. 1991. Coping with ignorance: the coarse filter approach for the maintaining of biodiversity. In: Kohn, K. A. ed. Balancing on the brink of extinction. Covelo, CA: Island Press: 266-281.

Hynes, J. D.; Brown, E. H., Jr.; Helle, J. H.; Ryman, N.; Webster, D. A. 1981. Guidelines for the culture of fish stocks for resource management. Canadian Journal of Fisheries and Aquatic Sciences. 38: 1867-1876.

Jakober, M. 1992. Influence of stream size and morphology on the seasonal distribution and habitat use of resident bull trout and westslope cutthroat trout in Western Montana. Progress Report. U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Johnson, K. N.; Franklin, J. F.; Thomas, J. W.; Gordon, J. 1991. Alternatives for management of late successional forests of the Pacific Northwest. A report to the Agriculture Committee and the Merchant Marine Fisheries Committee of the U. S. House of Representatives. 59 p.

King, J. G. 1989. Streamflow responses to road building and harvesting: a comparison with the equivalent clearcut area procedure. Res. Pap. INT-401. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Lande, R. 1988. Genetics and demography in biological conservation. Science. 241: 1455-1460.

Leary, R. F.; Allendorf, F. W.; Forbes, S. H. 1991. Conservation genetics of bull trout in the Columbia and Klamath rivers. Wild Trout and Salmon Genetics Laboratory Report. Missoula MT: University of Biological Sciences, University of Montana.

Leathe, S. A.; Enk, M. D. 1985. Cumulative effects of microhydrodevelopment on the fisheries of the Swan River drainage, Montana. Volume I: Summary Report. Kalispell, MT: Montana Department of Fish, Wildlife and Parks.

Leigh, E. D. 1981. The average lifetime of a population in a varying environment. Journal of Theoretical Biology. 90: 213-239.

MacLean, J. A.; Evans, D. O. 1981. The stock concept, discreteness of fish stocks, and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. 38: 1889-1898.

Markle, D. F. 1992. Evidence of bull trout x brook trout hybrids in Oregon. In: Howell, P. J.; Buchanan, D. V. eds. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society: 58-67.

McGurk, B. J. 1989. Predicting stream temperature after riparian vegetation removal. Gen. Tech. Rep. PSW-110. Berkeley, CA: U.S. Department of Agriculture, Forest Service.

McIntyre, J. D.; Reisenbichler, R. R.; Emlen, J. M.; Wilmot, R. L.; Finn, J. E. 1988. Predation of Karluk River sockeye salmon by coho salmon and char. Fishery Bulletin 86:611-616.

McPhail, J. D.; Murray, C. B. 1979. The early life-history and ecology of Dolly Varden (Salvelinus malma) in the Upper Arrow Lakes. Vancouver, British Columbia: Department of Zoology and Institute of Animal Resources, University of British Columbia.

Mongillo P.E. 1992. The distribution and status of bull trout/Dolly Varden in Washington state. In Bull trout/Dolly Varden management and recovery plan. Washington Department of Wildlife, Fisheries Management Division Report 92-22.

Morrison, G.; Barbosa, P. 1987. Spatial heterogeneity, population regulation, and local extinction in simulated host-parasitoid interactions. Oecologia. 73: 609-614.

Moyle, P. B.; Sato, G. M. 1991. On the design of preserves to protect native fishes. In: Minckley, W. L.; Deacon, J. E. eds. Battle against extinction: native fish management in the American West. Tucson, AZ: University of Arizona Press: 155-173.

Mullan, J. W.; Williams, K.; Rhodus, G.; Hillman, T.; McIntyre, J. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. U.S. Fish and Wildlife Service. Monograph 1. 60 p.

Murphy, D. D.; Noon, B. R. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. Ecological Applications. 2(1): 3-17.

Needham, P. R.; Vaughan, T. M. 1952. Spawning of the Dolly Varden, Salvelinus malma, in Twin Creek, Idaho. Copeia. 3: 197-199.

Peterman, R. M. 1977. A simple mechanism that causes collapsing stability regions in exploited salmon populations. Journal of the Fisheries Research Board of Canada. 34: 1130-1142.

Peterman, R. M.; Gatto, M. 1978. Estimation of functional responses of predators on juvenile salmon. Journal of the Fisheries Research Board of Canada. 35: 797-808.

Phillips, R. B.; Pleyte, K. A.; Brown, M. R. 1992. Salmonid phylogeny inferred from ribosomal DNA restriction maps. Canadian Journal of Fisheries and Aquatic Sciences. 49: 2345-2353.

Pratt, K. L. 1985. Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Boise.

Pratt, K. L. 1992. A review of bull trout life history. In: Howell, P. J.; Buchanan, D.V. eds. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society: 5-9.

Pulliam, H. R. 1988. Sources, sinks and population regulation. American Naturalist. 132(5): 652-661.

Quinn, J. F.; Hastings, A. 1987. Extinction in subdivided habitats. Conservation Biology. 1: 198-207.

Ratliff, D. E. 1992. Bull trout investigations in the Metolius River-Lake Billy Chinook system. In: Howell, P. J.; Buchanan, D. V. eds. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society: 37-44.

Ratliff, D. E.; Howell, P. J. 1992. The status of bull trout populations in Oregon. In: Howell P. J.; Buchanan, D. V. eds. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society: 10-17.

Reeves, G. H.; Sedell, J. R. 1992. An ecosystem approach to the conservation and management of freshwater habitat for anadromous salmonids in the Pacific Northwest. Trans. 57th N.A. Wild. and Nat. Res. Conf. 57: 408-415.

Reisenbichler, R. R.; McIntyre, J. D.; Solazzi, M. F.; Landino, S. W. 1992. Genetic variation in steelhead of Oregon and Northern California. Transactions of the American Fisheries Society. 121: 158-169.

Rieman, B. E.; Apperson, K. A. 1989. Status and Analysis of Salmonid Fisheries: Westslope cutthroat trout synopsis and analysis of fishery information. Job Performance Report, Project F-73-R-11, Subproject II, Study 1, Job 1. Boise, ID: Idaho Department of Fish and Game.

Rieman, B. E.; Myers, D. L. 1991. Costs, benefits, and risks of salmonid predators in kokanee waters. Job Completion Report, Project F-73-R-13, Subproject II, Study II, Job I. Boise, ID: Idaho Department of Fish and Game.

Rieman, B. E.; J. D. McIntyre. 1993. Habitat and Demographic Requirements of Bull Trout. USDA-Forest Service, Intermountain Research Station GTR (In Press).

Rishel, G. B.; Lynch, J. A.; Corbett, E. S. 1982. Seasonal stream temperature changes following forest harvesting. Journal of Environmental Quality. 11(1): 112-116.

Saunders, H. R.; Hobbs, R. J.; Margules, C. R. 1990. Biological consequences of ecosystem fragmentation: a review. Conservation Biology. 5: 18-32.

Schlosser, J. J. 1982. Trophic structure reproductive success and growth rate of fishes in a natural and modified headwater streams. Canadian Journal of Fisheries and Aquatic Sciences. 39: 968-978.

Schlosser, J. J. 1991. Stream Fish Ecology: a landscape perspective. Bioscience. 41: 704-712.

Sedell, J. R.; Reeves, G. H.; Hauer, F. R.; Stanford, J. A.; Hawkins, C. P. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management. 14: 711-724.

Shaffer, M. L. 1987. Minimum viable populations; coping with uncertainty. In: Soulé, M. E. ed. Viable populations for Conservation. Cambridge University Press, Cambridge: 69-86.

Shaffer, M. L. 1991. Population viability analysis. In: Decker, D. J.; Krasny, M. E.; Goff, G. R.; Smith, C. R.; Gross, D. W. eds. Challenges in the conservation of biological resources. Boulder, CO: Westview Press: 107-118.

Shaffer, M. L.; Samson, F. B. 1985. Population size and extinction: a note on determining critical population sizes. The American Naturalist. 125: 144-151.

Shepard, B.; Pratt, K.; Graham, P. 1984. Life histories of westslope cutthroat and bull trout in the upper Flathead River Basin, Montana. Kalispell, MT: Montana Department of Fish, Wildlife and Parks.

Sjogren, P. 1991. Extinction and isolation gradients in metapopulations: the case of the pool frog (Ranale ssonae). Biological Journal of the Linnean Society. 42: 135-147.

Stacey, P. B.; Taper, M. 1992. Environmental variation and the persistence of small populations. Ecological Applications. 2(1): 18-29.

Sullivan, K.; Lisle, T. E.; Dolloff, C. A.; Grang, G. E.; Reid, L. M. 1987. Stream channels: The link between forests and fishes. In: Salo, E. O.; Cundy, T. W. eds. Streamside management: forestry and fishery interactions. Seattle, WA: University of Washington: 39-97.

Taylor, B. 1991. Investigating species incidence over habitat fragments of different areas -- a look at error estimation. Biological Journal of the Linnean Society 42:177-191.

Thomas, G. 1992. Status report: bull trout in Montana. Helena MT: Montana Department of Fish, Wildlife, and Parks.

Thurow, R. 1987. Evaluation of the South Fork Salmon River steelhead trout fishery restoration program. Lower Snake River Fish and Wildlife Compensation Plan Contract No. 14-16-0001-86505, Job Completion Report. Boise, ID: Idaho Department of Fish and Game.

USDA. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. (Draft manuscript).

Weaver, T. M. 1991. Coal Creek fisheries monitoring study No. IX and forest-wide fisheries monitoring - 1990. Kalispell, MT: Montana Department of Fish, Wildlife and Parks, Special Projects.

Weaver, T. M. 1992. Coal Creek fisheries monitoring study No. X and forest-wide fisheries monitoring - 1991. Kalispell, MT: Montana Department of Fish, Wildlife and Parks, Special Projects.

Weaver, T.; Fraley, J. 1991. Fisheries habitat and fish populations. Flathead Basin Forest practices, water quality and fisheries cooperative program. Kalispell, MT: Flathead Basin Commission.

Weaver, T. M.; White, R. G. 1985. Coal Creek fisheries monitoring study number III. Quarterly progress report. Bozeman, MT: U.S. Department of Agriculture, Forest Service, Montana State Cooperative Fisheries Research Unit.

Williams J. E. and seven coauthors. 1989. Fish of North America endangered, threatened, or of special concern. Fisheries. 14(6): 2-20.

Yount, J. D.; Niemi, G. J. 1990. Recovery of lotic communities and ecosystems from disturbance -- a narrative review of case studies. Environmental Management. 14(5): 547-569.

APPENDIX A

BULL TROUT INFORMATION SURVEY DATA SHEET
Definitions and Instructions

DRAINAGE/POPULATION NAME: Name the bull trout group being described. For purposes of this information survey, bull trout inhabiting a distinct aquatic ecosystem or interconnected drainage basin with no barriers to genetic exchange may be considered a "population" (e.g., Flathead Lake/ Upper Flathead River population). However, if available information suggests further subdivision into separate populations that would be described differently below, then use separate data sheets for these "populations" (e.g., North Fork Flathead River population, Middle Fork Flathead River population).

STREAM OR DRAINAGE BASIN REFERENCE NUMBER(S): Use EPA Stream Reach Numbers if available and appropriate; otherwise, use State I.D. number or water code.

LIFE HISTORY: Specify one or more of the following life history patterns which the population exhibits.

RESIDENT - Entire life cycle is completed in low order stream systems with little or no seasonal migrations.

FLUVIAL - Mature fish reside in large streams but migrate into smaller tributaries to spawn. Juveniles rear for several years in small streams.

ADFLUVIAL - Mature fish reside in lakes but migrate into streams to spawn. Juveniles typically rear for several years in stream environments.

ANADROMOUS - Mature fish reside in ocean but migrate up rivers to spawn. Juveniles rear in streams.

UNKNOWN

REMNANT POPULATION: Specify whether this is a remnant population; that is, the fish are known to be present but in very low numbers. Although longterm viability is questionable, the population may constitute a significant portion of the species gene pool.

STATUS: To classify, reliable information from within the last five years is needed; otherwise, status should be considered "unknown".

DECLINING - Recent data indicates shrinking distribution or declining abundance.

STABLE - No indication of recent population change; future trend unknown, but habitat degradation, non-native species interaction, overharvest, or other factors may pose threats to the population.

SECURE - No indication of recent population change; habitat degradation is unlikely; low potential for non-native species interaction, overharvest, or other adverse effects.

INCREASING - Recent data indicates significant upward population trend.

UNKNOWN - Presence established but insufficient information to classify.

FACTORS INFLUENCING STATUS: If applicable, the following factors should be rated as negative (-) or, in some cases, positive (+) influences on the population status. Leave blank if not applicable or unknown.

ACCESSIBILITY - If the population is vulnerable to overharvest because of ready access, rate negative. If not, rate positive.

HARVEST REGULATIONS - If current regulations appear to provide inadequate protection for the population, rate negative. If regulations are promoting population increases, rate positive. If no effect, leave blank.

POACHING - Rate negative if poaching is a significant threat to the population.

NON-NATIVE SPECIES INTERACTION - Rate negative if non-native fish species are having adverse effects on the population; rate positive if beneficial (e.g., increased forage base).

HABITAT CHANGE - If habitat change is occurring, rate it as negative or positive influences on the population for the following components:

Physical Condition - includes diversity, substrate, cover, LOD, etc.
Water Flow - includes quantity and fluctuation.
Water Quality - includes chemical parameters and temperature.

MAJOR CAUSES OF HABITAT CHANGE: Check all of the following that apply.

FOREST MANAGEMENT - Road construction and timber harvest, riparian management, watershed management.

AGRICULTURE - Irrigation, agricultural runoff, etc.

MINING GRAZING HYDROPOWER OTHER

DATA AVAILABLE: Indicate what information has been collected and when, as follows.

HABITAT - Surveys, walk-throughs, etc.

POPULATION - Presence/absence, shocking, snorkel, creel, genetics, etc.

COMMENTS: Include any relevant or explanatory material.

CONTACT: List persons who could best answer questions about this population.

NAME and PHONE NO.

APPENDIX B

Bull trout population data sheets.

STATE _____

FOREST _____

1. DRAINAGE/POPULATION NAME _____

   EPA DRAINAGE BASIN # _____

2. LIFE HISTORY

   Resident _____

   Fluvial _____

   Adfluvial _____

   Anadromous _____

   Unknown _____

3. REMNANT POPULATION Yes ___ No ___ Unknown ___

4. STATUS

   Declining _____

   Stable _____

   Secure _____

   Increasing _____

   Unknown _____

5. FACTORS INFLUENCING STATUS (+ or -)

   A. Access _____

   B. Harvest Regulation _____

   C. Poaching _____

   D. Non-native interaction _____

E. Habitat

1. Physical _____
2. Flow _____
3. Water Quality _____

F. Major Causes of Habitat Change

1. Forest Management _____
2. Agriculture _____
3. Mining _____
4. Grazing _____
5. Hydropower _____
6. Other _____

6. DATA AVAILABLE

Habitat Yes _____ No _____

Population Yes _____ No _____

7. COMMENTS:

8. CONTACT(S)

Name(s) _____ Phone (_____)

_____ Phone (_____)

_____ Phone (_____)

Table 1. Life history and status of bull trout populations in, Idaho, Montana, Nevada, Oregon and Washington. Tabular entries are percentages. RES=resident, FLV=fluvial, ADF=adfluvial, ANA=anadromous, UNK=unknown, DEC=declining, STB=stable, SEC=secure, INC=increasing.

		Life History					Status				
State	Estimated Populations	RES	FLV	ADF	AND	UNK	DEC	STB	SEC	INC	UNK
Idaho	72	38	47	8	0	32	32	15			53
Montana	234	74	33	35	0	7	38	15	2	3	42
Nevada	1		100		0						100
Oregon	54	65	50	11	0	7	26	8	9		57
Washington	77	42	26	21	36	35	12	26	6	1	55
Total	438	61	36	25	6	16	31	16	3	2	49

Table 2. Availability of bull trout habitat and population data for Idaho, Montana, Nevada, Oregon and Washington. Tabular entries are percentages.

State	Populations	Habitat Data Available	Population Data Available
Idaho	72	57	53
Montana	234	49	53
Nevada	1	100	100
Oregon	54	95	98
Washington	77	53	52
Total	438	57	58

Table 3. Status of bull trout populations in Oregon (Ratliff and Howell 1992).

Status	Number of Populations	Percentage
Low risk of extinction	9	14
Of special concern	13	20
Moderate risk of extinction	19	29
High risk of extinction	12	18
Probably extinct	12	18

Table 4. Status of bull trout populations in Washington (data from Mongillo 1992).

Status	Number of Populations	Percentage
No risk of extinction	6	8
Low risk of extinction	14	18
Moderate risk of extinction	6	8
High risk of extinction	9	11
Probably extinct	3	4
Insufficient information	42	53

Table 5. Risk of bull trout extinction in stream reaches in Montana (data from Thomas 1992).

Risk of Extinction	Number of Reaches	Percentage
3 (lowest)	6	1
4	2	0
5	24	3
6	162	19
7	143	17
8	161	19
9	110	13
10	91	11
11	46	6
12 (highest)	86	10

Table 6. Factors affecting the habitat quality of bull trout populations in Idaho, Montana, Nevada, Oregon and Washington. Table entries are percentages.

State	Populations	Habitat Quality						Factors Suppressing Habitat Quality					
		Physical		Flow		Water Quality		Forest Mgmt.	Agriculture	Mining	Grazing	Hydro Power	Other
		+	-	+	-	+	-						
Idaho	72	7	57	8	22	6	43	53	14	19	38	6	25
Montana	234	17	50	9	31	9	21	54	25	10	16	26	29
Nevada	1		100					100					
Oregon	54	28	56	26	52	30	54	82	44	15	48	15	37
Washington	77	34	34	42	20	51	16	52	14	7	9	23	17
Total	438	20	49	16	30	18	28	57	24	11	22	21	27

+ = beneficial
- = adverse

Table 7. Non-habitat factors affecting bull trout populations in Idaho, Montana, Nevada, Oregon and Washington. Tabular entries are percents.

State	Populations	Access		Harvest Regulations		Poaching		Non-native Interaction	
		+	-	-	+	-	+	+	-
Idaho	72	6	53	7	38		14		17
Montana	234	7	42	13	21		42	3	60
Nevada	1	100	100		100		100		
Oregon	54	22	43	59	11	9	4		65
Washington	77	25	29	95	3		34		33
Total	438	12	42	32	19	1	31	1	49

\+ = beneficial
\- = adverse